



Topographic data generated from Radarsat Images Over West Kalimantan, Indonesia

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Abstract. Indonesia is a tropical country which has dominant cloud coverage, and some of the area has cloud cover almost all year long. Mapping by optical sensors, especially with Photogrammetric method shows a very good result, but the main constraint is cloud cover conditions, and this was the weakness point of this method.

This study describe the technique for deriving Topographic data from Radarsat Synthetic Aperture Radar stereo image pair and apply it to an image pair over West Kalimantan, Indonesia. This paper contains also brief discussion of the use of stereo SAR to derive Digital Elevation Model, the site condition and the source of validation data. The result shows that Radarsat data recommended only for 1 : 100.000 or smaller.

Keywords: *Radarsat; Photogrammetry; DEM; Radargrammetry; West Kalimantan.*

1 Introduction

The aim of this study is to assess the Radarsat imagery for topographic mapping, especially the geometric point of view by radargrammetric processing. Topographic condition will represented by Digital Elevation Model (DEM) of the study area.

When a target or study area is imaged from two different incidence angles, in the case of spaceborne radar, differential relief displacements cause image parallax on the radar image. This process allows for radar images to be viewed stereoscopically. For same side stereo airborne radar, has been used operationally for some years to generate topographic maps by radargrammetric technique, but since Radar satellite launched in 1995 (Radarsat), implementation radar satellite become promising for some application, especially for cloudy area, to obtain topographic map.

Radarsat sensors has some possibilities to arrange incidence angle into 3 positions, and this was the main different comparing with Radar imageries came from ERS satellite, which has fix position incidence angle, 23° .

In addition, to provide stereoscopic viewing, radar parallax may be measured and used to compute approximate heights.

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Different with aerial photography, the acquisition data for radar imageries is always done by side looking, while aerial photography always done by vertical optical axis.

2 Geometric Configuration

The basis of any stereo process is that, by looking at the same point from two different positions in space. This is illustrated in Fig.1 below, where relief displacements cause image parallax on the radar image and toward the sensor.

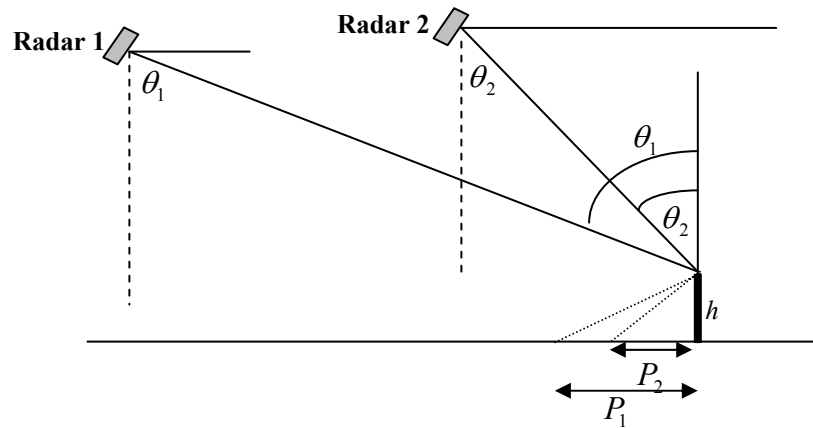


Figure 1 Image parallax on the radar image.

In Figure 1, h is object height, P_1 is parallax from 1st image, P_2 is parallax from 2nd image and dP is radar parallax $= |P_1 - P_2|$.

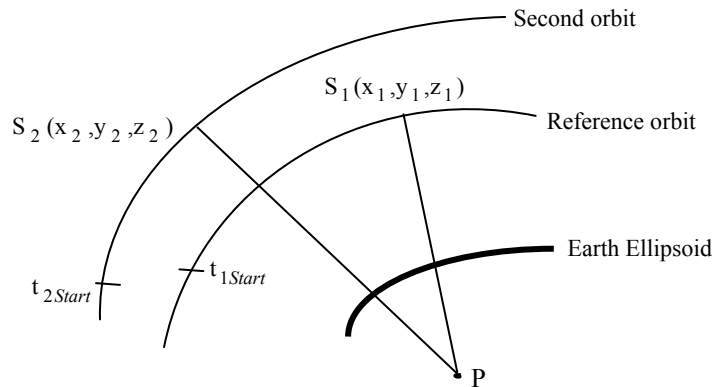


Figure 2 Imaging geometry with zero Doppler position (S_1 and S_2) of the two sensors with reference to the point P on the Earth Ellipsoid.

From the same side stereo imaging geometry, we can calculate the three-dimensional position of a point as illustrated in Figure 2.

The coordinate of P are calculated by solving the following system of nonlinear equations:

$$G_1(x, y, z) \equiv \frac{P_x^2 - P_y^2}{a^2} - \frac{P_z^2}{b^2} = 0 \quad \text{Ellipsoid equation} \quad (1)$$

$$G_2(x, y, z) \equiv \frac{2(\bar{S} - \bar{P})(\bar{S}' - \bar{P}')}{\lambda|\bar{S} - \bar{P}|} = 0 \quad \text{SAR Doppler equation} \quad (2)$$

$$G_3(x, y, z) \equiv R_0 + m_r \cdot j - |\bar{S} - \bar{P}| = 0 \quad \text{Slant range equation} \quad (3)$$

where: $\bar{P}(P_x, P_y, P_z)$ is the point on the ellipsoid

\bar{S}	is the respective sensor position
\bar{P}'	is the speed of point \bar{P} in the coordinate system concerned relative to the inertial system
\bar{S}'	is the respective sensor velocity
j	is the image coordinate in range
R_0	is the offset in the slant range
m_r	is the slant range sampling interval
λ	is the radar wavelength
a and b	are the parameters of the two semi axis of the ellipsoid

The solution of this system of nonlinear equations is obtained by iteration using Newton's method.

The three dimensional position vector \bar{P} can be transformed into map coordinates (e.g. Northings and Eastings) and a height above a reference ellipsoid or geoid. When arranged into a regular map coordinate grid, the heights are referred to as Digital Elevation Model (DEM).

Consider the same side viewing configuration illustrated in Fig. 1, where we have a target at height h viewed at incidence angle θ_1 and θ_2 respectively.

Trigonometric relation shows that the displacement of the target from its true position when viewed from Radar sensor,

$$P_1 = h \cot \theta_1 \quad \text{and} \quad P_2 = h \cot \theta_2 \quad (4)$$

If we are to gain stereo information from the two views, the only condition is that the difference in displacement caused by viewing from the two positions is measurable. This means,

$$dP = | P_2 - P_1 | \quad (5)$$

where dP is the spatial resolution image, or radar parallax.

We can easily invert this equation to find the minimum height difference measurable from stereo SAR for any given spatial resolution and incidence angle, this means,

$$h = \frac{dP}{h \cot \theta_2 \pm h \cot \theta_1} \quad (6)$$

h is the minimum height measurable.

3 Stereo SAR Processing

The processing stages in Radargrammetric for Radarsat imageries are illustrated in flow diagram as shown in Figure 3.

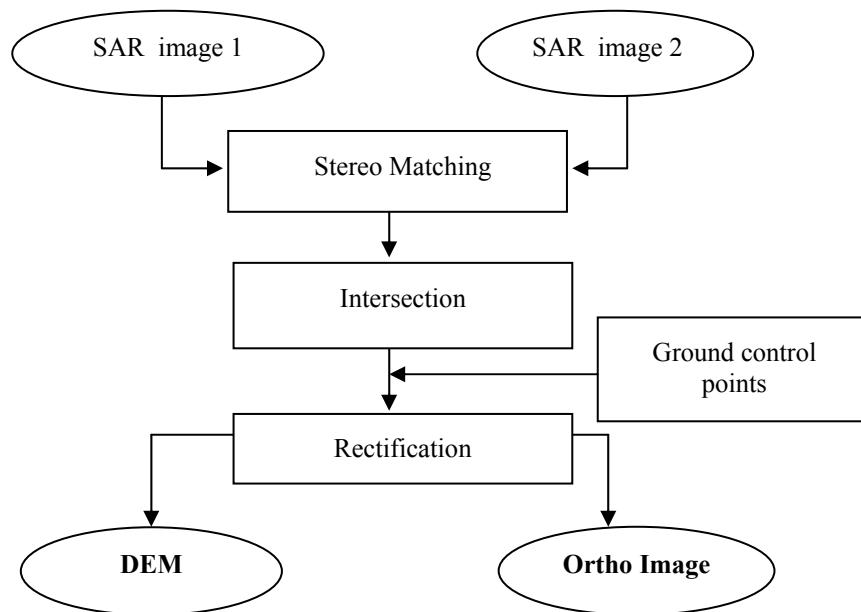


Figure 3 Stereo SAR Processing stages.

3.1 Stereo Matching

Stereo matching covers all aspects of data input and the matching itself, which involves the systematic identification of the same points in the two different images. Radar parallax are measured for each point and eliminate these Radar parallax in order to obtain the relative stereoscopic model.

3.2 Intersection

Intersection is a well define problem and has been approached through radargrammetric modeling. The disparity between the two images is converted into grid reference using specified ellipsoid, WGS'84.

3.3 Rectification

In this stage, the irregular grid of position and height is placed into regular map projection grid, essentially rectifying and geocoding the data.

4 Site Description and Radarsat Data

West Kalimantan is always covered by cloud almost all year long, and has heterogen topographic condition, from flat, hilly and mountainous terrain.

Figure 4 shows the location of study area in west Kalimantan, and Figure 5 shows the coverage of the Radarsat images over study area.



Figure 4 Kalimantan Area.

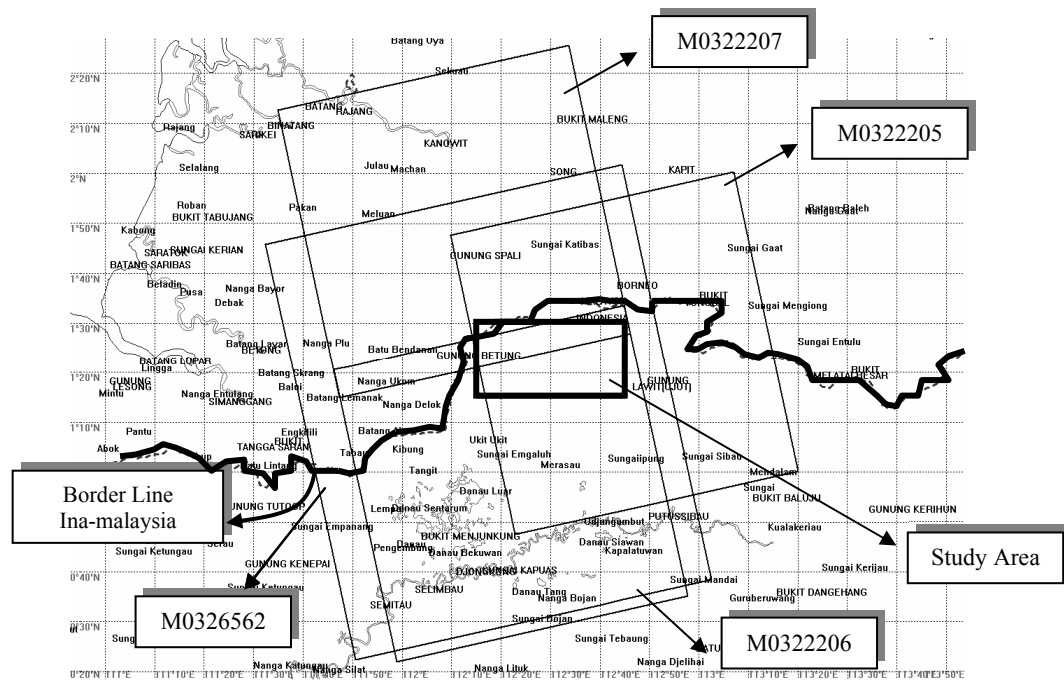


Figure 5 Radarsat coverage over study area.

Table 1 and Table 2 show the specification and total data using for this study.

Table 1 Radarsat data specification.

No	Scene ID	Beam Mode	Date	Orbit
1	M0326562	Wide 2	27 June 2003	Ascending
2	M0322206	Standart 7	26 April 2003	Ascending
3	M0322205	Standart 6	9 April 2003	Ascending
4	M0322207	Standart 7	26 April 2003	Ascending

Table 2 Radarsat Incident angle.

No	Scene ID	Incident angle (degree)	Latitude (center)	Longitude (center)
1	M0326562	35.30600	N 01:12	E 112:17
2	M0322206	47.01400	N 00:57	E 112:21
3	M0322205	44.22100	N 01:23	E 112:44
4	M0322207	47.02300	N 01:50	E 112:14

5 Generation of Topographic Data over West Kalimantan Site

Although all the existing Radarsat data for this study (4 scenes) have the same ascending orbit, each scene have different beam mode. Radargrammetric processing done using PCI 8.3 version software, and Photogrammetric map (1:50.000) used for validation.

Flow diagram of the study, illustrated in Figure 6 below,

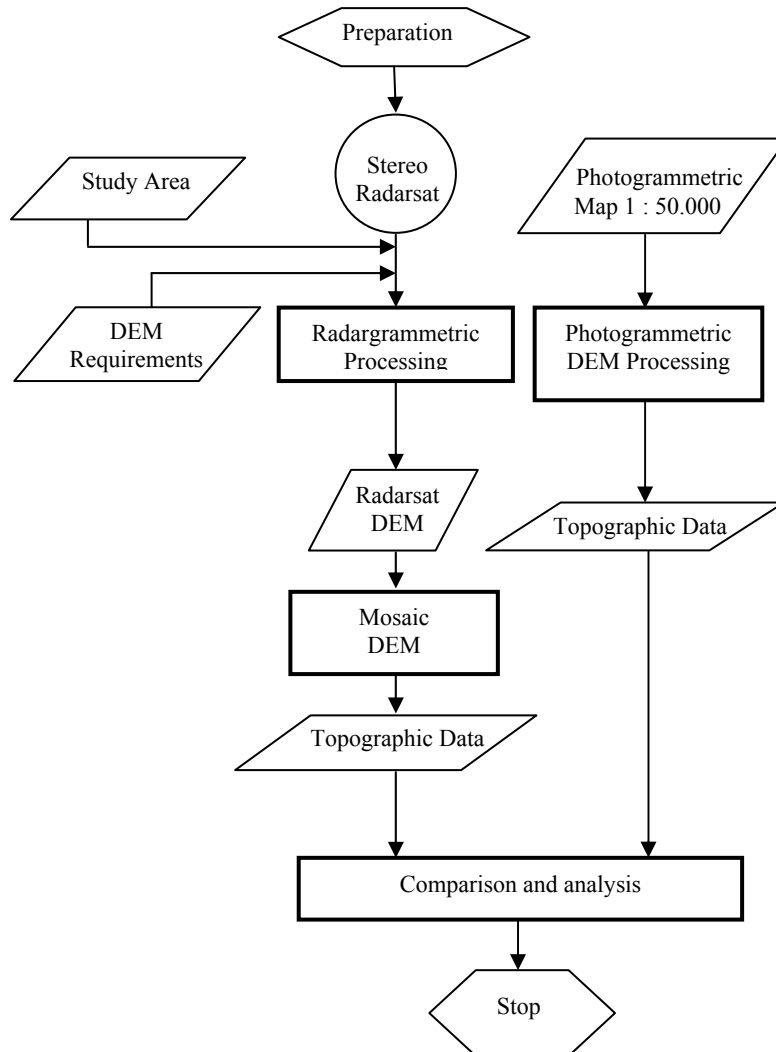


Figure 6 Study methodology.

After executing SAR stereo radargrammetric processing, the result of Radarsat DEM illustrated in Figure 7, and Figure 8 illustrated the result of Photogrammetric DEM.

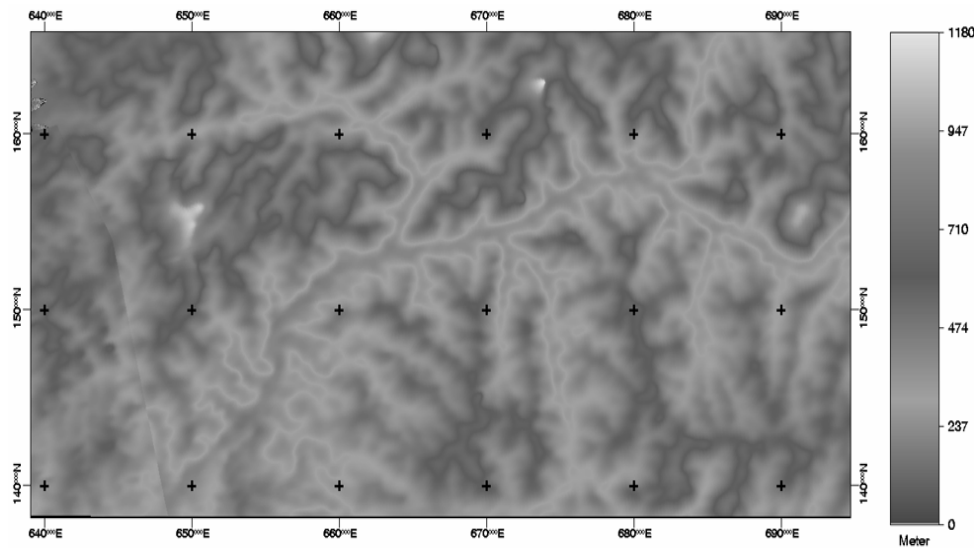


Figure 7 Radarsat DEM.

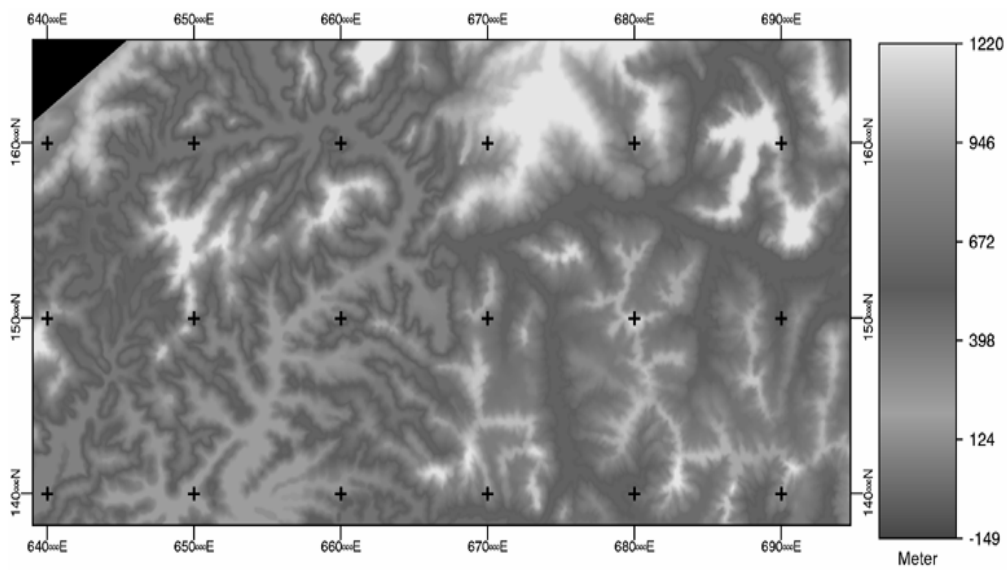


Figure 8 Photogrammetric DEM.

6 Comparison and Analysis

As Photogrammetric DEM used for validation, the different value from two sources data (Photogrammetric DEM and Radarsat DEM) for any point i is x_i , then we can calculate the *RMSE* using

$$RMSE = \pm \sqrt{\frac{\sum (x_i)^2}{n}}$$

where n = total evaluation points

x_i = (Radarsat DEM – Photogrammetric DEM).

Table 3 shows the result of *RMSE* From Radarsat DEM,

Table 3 Result of *RMSE* from Radarsat DEM.

Stereo pair	Column (pixel)	Line (pixel)	n	RMSE (meter)
Radarsat	1498	760	1,138,480	35.049

The DEM accuracy can be divided into groups or classes. For a good map, 90 % of the heights should have an accuracy not more than half contour interval or if less than 90 %, we will obtain less accuracy map.

Table 4 illustrated the probability of errors for the map classes,

Table 4 Probability of errors (Petrie & Kennie, 1990).

Prob. of errors (S)	Percentage (1/2 contour interval)	Map Class
1.6449	90.00%	I
1.5	86.60%	II
1.0	68.27%	III
0.6745	50.00%	IV

The results describe above shows that it is possible to derive topographic data from stereo Radarsat images by radargrammetric technique.

A preliminary quality assessment is described above over specific area of interest in West Kalimantan.

For topographic map in the scale of 1 : 100.000, contour interval is 50 meters, so for a good map, 90% should have an accuracy not more than half contour interval, means 25 meters.

$$1.6449 \times \sigma = 25 \text{ meters}$$

$$\sigma = 15.198 \text{ meters}$$

Radarsat result illustrated at Table 3 shows that RMSE is 35.049 meters, is not accepted for a good map, but accepted for 4th Class Topographic map with 50% of the height should have not more than half contour interval,

$$0.6745 \times \sigma = 25 \text{ meters}$$

$$\sigma = 37.064 \text{ meters}$$

For Topographic map in the scale of 1 : 250.000 contour interval is 125 meters. From the same Table 3, for a good map, (1st class map)

$$1.6449 \times \sigma = 62.5 \text{ meters}$$

$$\sigma = 37.996 \text{ meters}$$

So, Radarsat result accepted for 1 : 100.000 Topographic map (4th Class) and accepted for 1 : 250.000 as a good map over study area.

Figure 9 shows the final Topographic data of the study area.

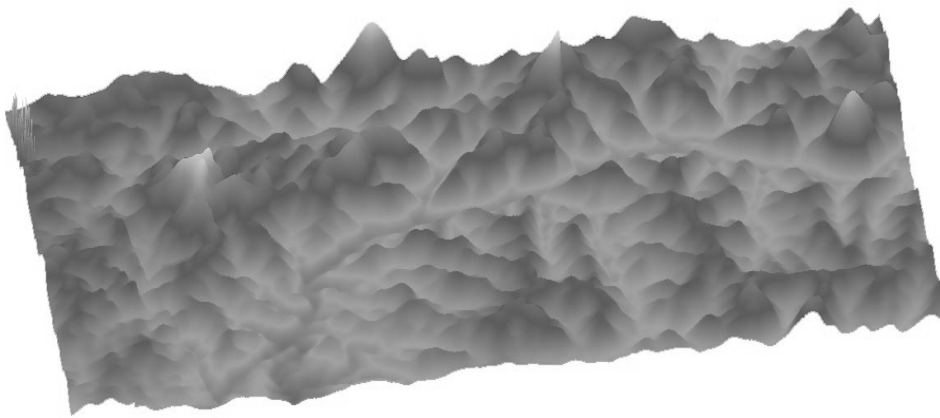


Figure 9 Final Topographic data of the study area (3D view).

Figure 10 shows that, if Radarsat Topography identical with Photogrammetric Topography, the topographic different will be flat. But in this case the different between both topography looks high different especially in mountainous/hilly area, this was because of topographic distortions caused by side looking

systems, e.g. Shadow, Forshortening, and Layover effects. Figure 11a, 11b, 11c illustrated the topographic distortions.

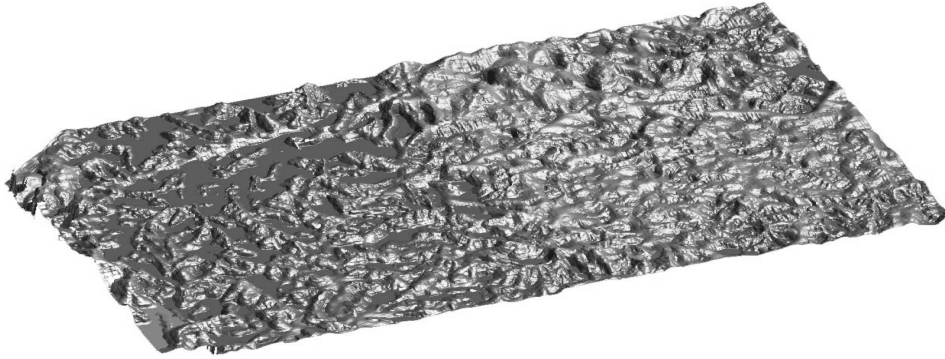


Figure 10 Different Radarsat and Photogrammetric (3-D views).

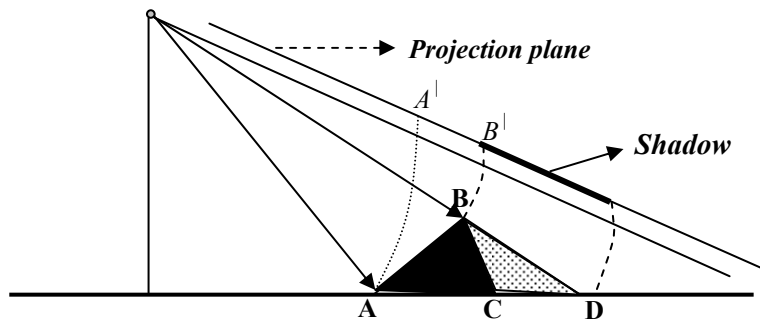


Figure 11 a Shadow effect (No information in the shadow area).

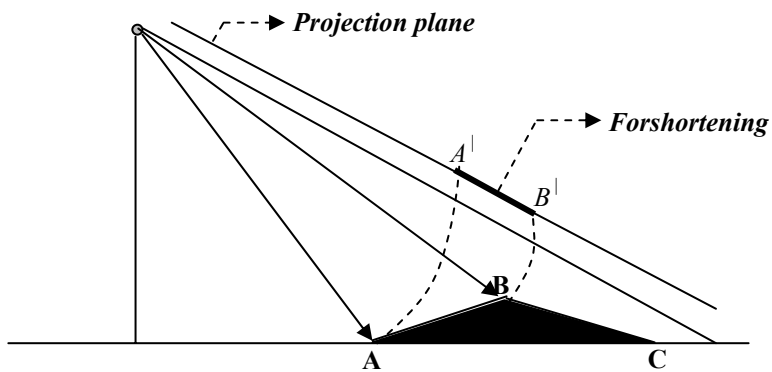


Figure 11b Forshortening effect ($A'B'$ become shorter).

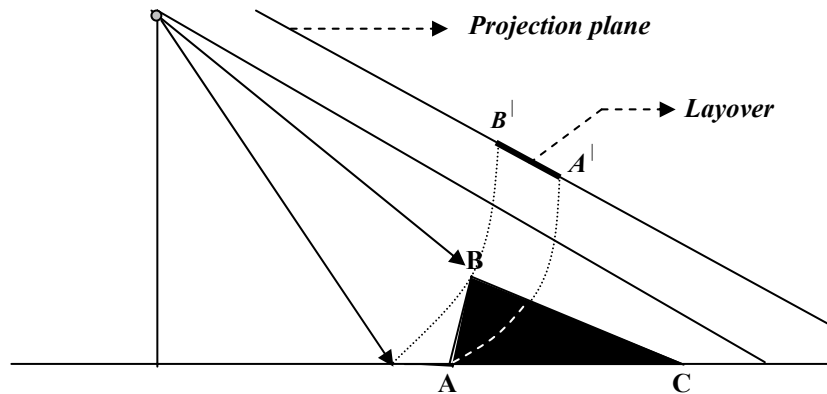


Figure 11c Layover effect (AB become $B'A'$ in the projection).

7 Conclusion and Recommendation

Base on the results previously described above, it can be concluded that Radargrammetric process for Radarsat images is not suitable for large scale, but should be used for 1 : 100,000 or smaller scale topographic map,

This study only investigates the use of the same side Radarsat stereo pair. Therefore more study is recommended with another stereo pairs combination, e.g,

- images from ascending and descending orbit modes;
- beam mode combination. (Fine, Standart or Wide beam); and
- use of Ground control points with corner reflectors.

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